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US 4653326 A

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(54) Acceleration sensor with etched vibratable tongue

(57) A sensor for vibration measurement, in particular for acceleration measurement, is proposed, which is produced from a support 20, 21 of monocrystalline material, from which at least one vibratable tongue 12 is etched out. In addition, there are means for the evaluation of the deflection of the at least one tongue. One or more electrode 131, 132 is arranged opposite the tongue and electrically isolated from it, so that the capacitive change between tongue and electrode is measurable as the tongue is deflected within the plane of the support layer 20. The layers 20, 21 are of n and p type conductivity to provide an etch stop.

FIG. 4

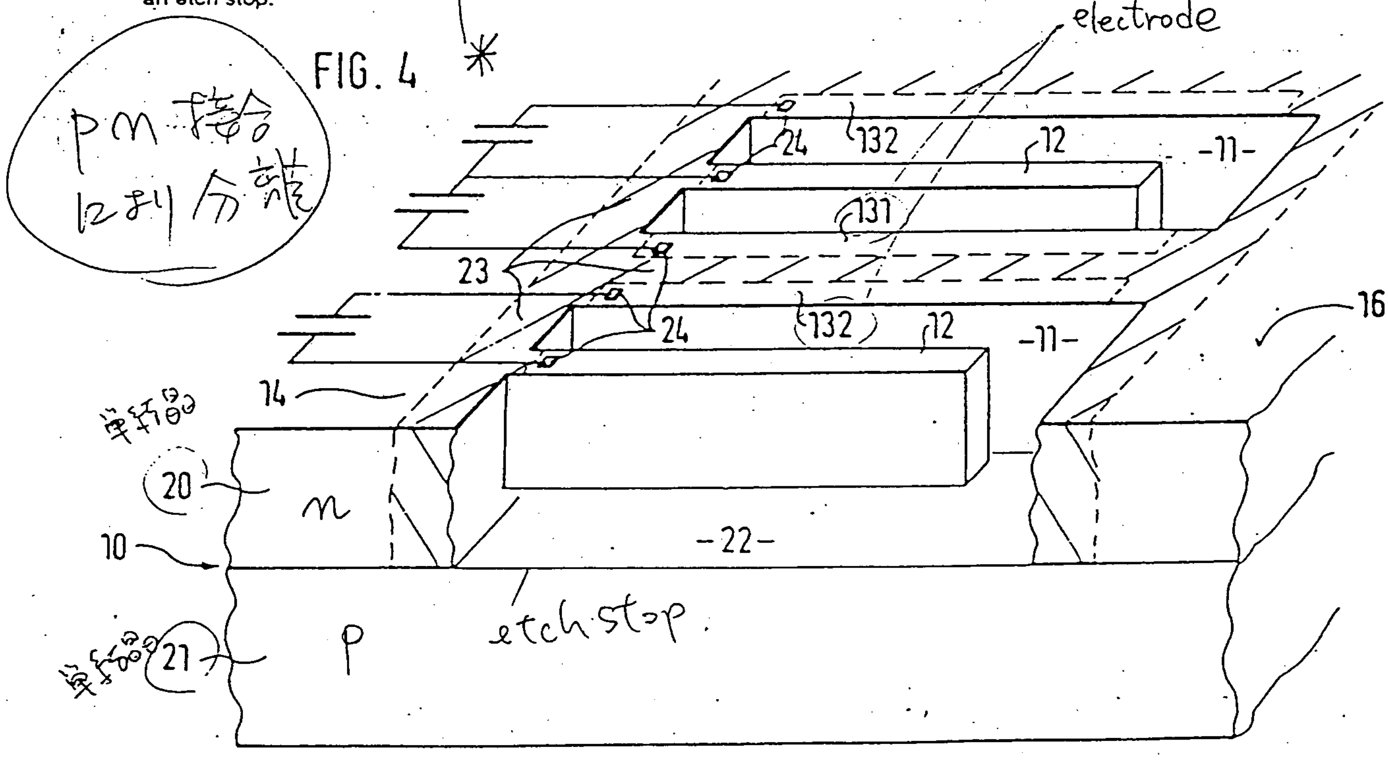

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FIG. 1

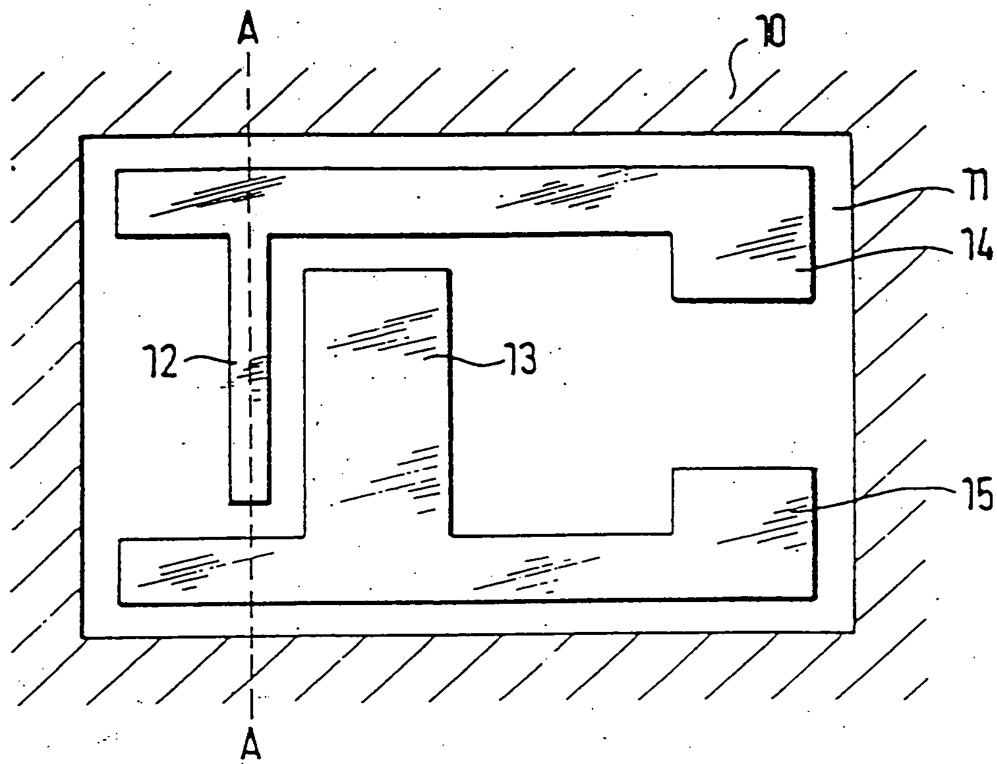


FIG. 2

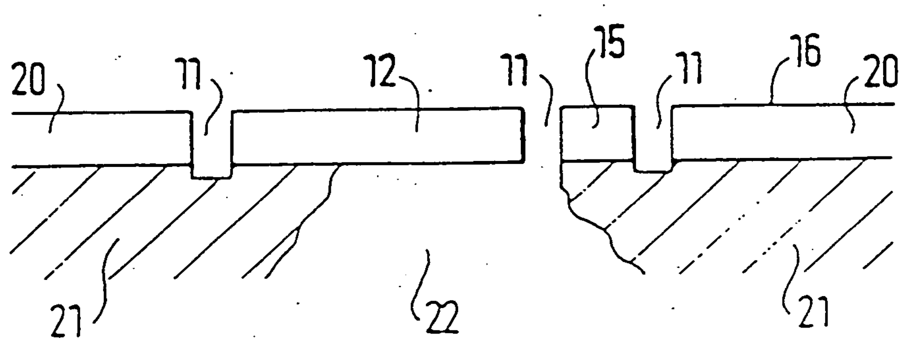
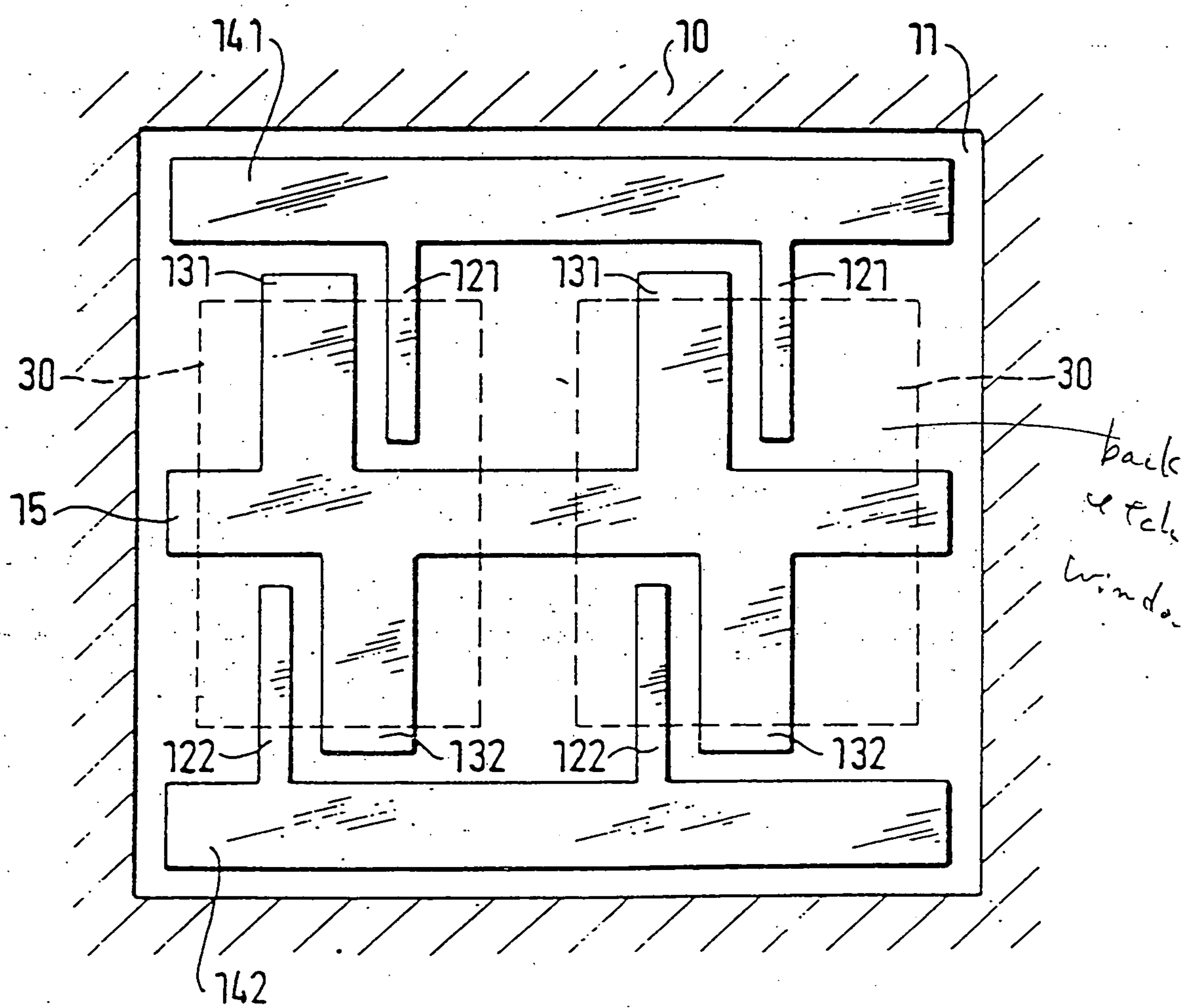


FIG. 3


141
10
11
131
121
131
121
30
30
back etch window
15
122
132
122
132
142

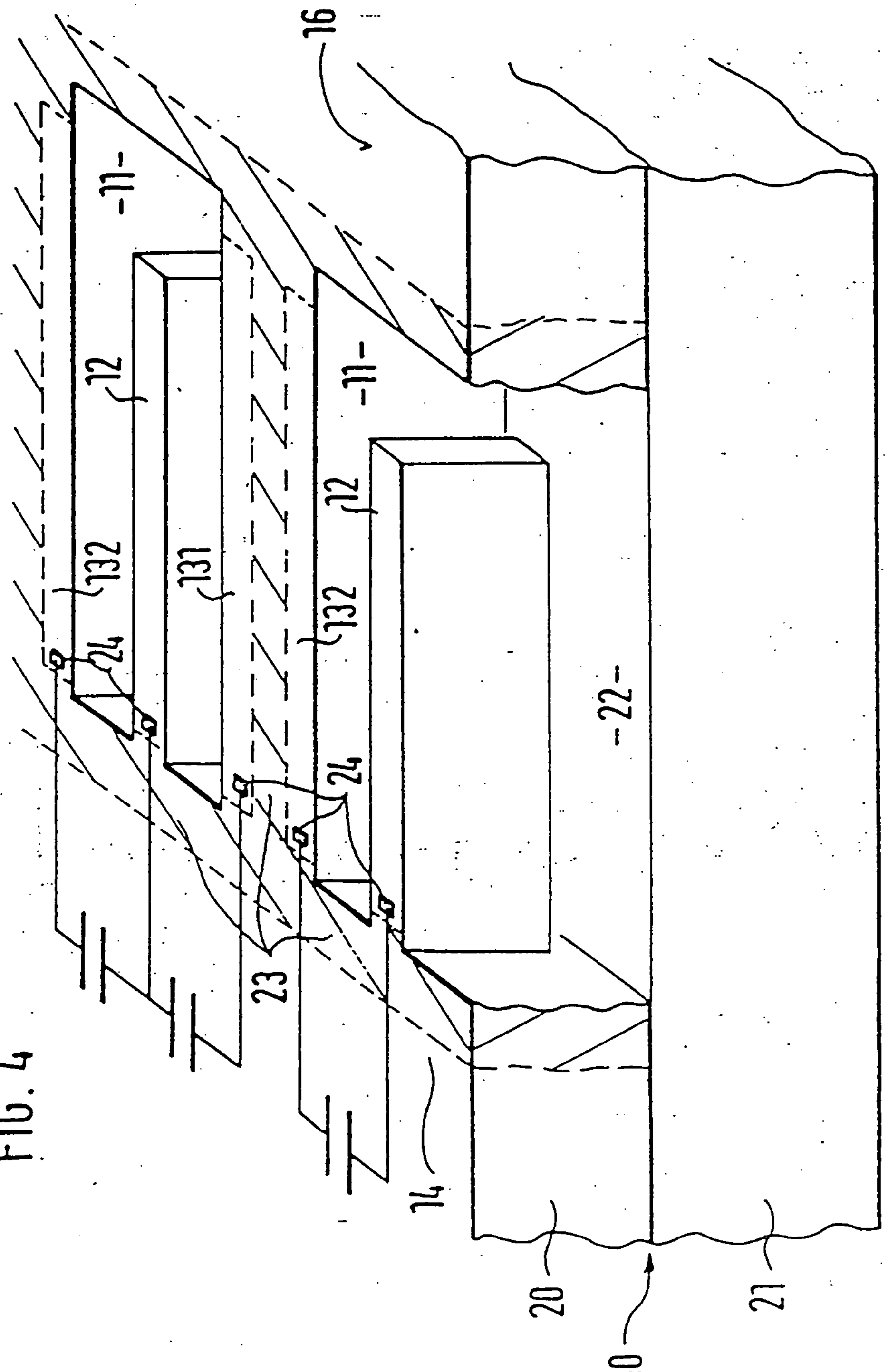


FIG. 4

Acceleration sensor

Prior art

The invention is based on a sensor for vibration measurement of the generic type of the main claim.

Patent application P 38 14 952 already discloses acceleration sensors based on silicon micromechanics in which a tongue which is suspended at one or more strips is deflected perpendicularly to the chip surface. The extension of the strips is determined with the aid of piezoresistances arranged in a Wheatstone bridge. The seismic mass of piezoresistively operating sensors requires a relatively large chip surface. Owing to the seismic mass designed as a tongue and its direction of vibration perpendicularly to the chip surface, an encapsulation of the sensor and a pressure reduction inside the sensor is often necessary, since the tongue vibration is otherwise damped too much. In addition piezoresistively operating sensors have a strong temperature sensitivity.

Patent application P 39 27 163, which is not a prior publication, discloses that structures can be etched out in semiconductor wafers.

Advantages of the invention

The sensor according to the invention with the characterising features of the main claim has in comparison the advantage that, due to the vertical arrangement of the tongues, sensors with very small chip surface can be realised. This arrangement also makes it possible for the sensor to be operated at normal pressure. It also

proves to be advantageous that the tongues vibrate in the plane of the chip and are thus protected by the chip itself in the event of overloading. It is to be regarded as a further advantage that the capacitive evaluation of the sensor signals only requires tongues of small thickness, since no piezoresistances have to be integrated in them.

Advantageous further developments of the sensor specified in the main claim are possible by the measures listed in the subclaims. A particular advantage of the sensor according to the invention is that the pn or np junction between the upper layer (20) and the lower layer (21) not only serves for isolation of the tongue (12) and of the electrode (13) with respect to the lower layer (21), but can also act as an etching stop limit in electrochemical undercutting of the tongue (12) from the support surface (16) or for back etching, which serves for isolation of the moveable tongue (12) with respect to the fixed electrode (13). It is advantageous that the quiescent capacitance of the sensor can be increased particularly easily by parallel connection of a plurality of capacitances formed in each case by a tongue (12) and a fixed electrode (13). A further advantage is the increase in sensor sensitivity by evaluating the difference in capacitance of two tongue/electrode arrangements which respond to acceleration with a mutually opposed change in capacitance, owing to the position of the respective moveable tongues (12) with respect to their fixed electrodes (13).

A further advantage is that the sensor can be produced by standard methods of the etching technique.

Drawing

Exemplary embodiments of the invention are represented in the drawing and explained in further detail in the description which follows.

Figure 1 shows the plan view of a sensor, Figure 2 a section of the sensor according to Figure 1 in the

A-Ā plane, Figure 3 and Figure 4 in each case show the plan view of a further sensor according to Figure 1.

Description of the exemplary embodiment

In Figure 1, 10 denotes a support of monocrystalline material, for which for example a silicon wafer is used. However, a wafer of any other semiconductor material, for example gallium arsenide or germanium, is also suitable. The support consists of a lower layer 21 and an upper layer 20, as is represented in Figure 2. The lower layer 21 is usually a p-type doped substrate and the upper layer 20 is an n-type doped epitaxial layer applied on the said lower layer. A reversed doping of the individual layers is equally possible, since both a pn junction and an np junction have an isolating effect when connected in the non-conducting direction. An etched trench 11, which is etched into the support surface 16 by anisotropic or other suitable etching procedures which produce vertical trenches, completely penetrates the upper layer 20 and results in two regions electrically isolated from each other. The one region comprises a tongue base 14 with a vibratable tongue 12 in the plane of the support and the other region comprises an electrode base 15 with the immoveable electrode 13. The tongue 12 is, for example, 5 μm wide, 1 to 2 mm long and 10 to 15 μm high. The longitudinal side of the tongue 12 is opposite the longitudinal side of the electrode 13, for example at a distance of 2 μm, this distance changing upon vibration of the tongue 12. The tongue base 14 and the electrode base 15 serve as electric terminals of the capacitance formed by tongue 12 and electrode 13. Figure 2 shows that the tongue 12 is exposed by an undercutting 22. An undercutting of the tongue 12 can take place for example by a back etching or a lateral undercutting from the front side. It is also possible to etch out a plurality of tongues and a plurality of electrodes with base from a support surface 16 and to combine them in a parallel

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connection of capacitive operating sensors, as for example the upper half of Figure 3 shows. Here, two tongues 121, which can vibrate in the plane of the support, extend perpendicularly from a tongue base 141 and, together with the two opposite immoveable electrodes 131, which extend from an electrode base 15, form two parallel-connected capacitances.

The sensor represented in Figure 3 again consists of the two-layered support 10, the upper layer 20 of which has a plurality of comb-shaped regions electrically isolated from one another by an etched trench 11. A beam-like tongue base 141, with two tongues 121 which can vibrate in the plane of the support and are perpendicular to the tongue base 141, is arranged in parallel with an identically structured tongue base 142 with likewise two tongues 122 which can vibrate in the plane of the support, so that the tongues 121 and 122 lie opposite each other. Inbetween there is, parallel with the two tongue bases 141 and 142, the electrode base 15, from which both two immoveable electrodes 131 extend in the direction of the tongue base 141 and two immoveable electrodes 132 extend in the direction of the tongue base 142. The number of tongues and electrodes can be varied as desired. The distance of the tongue base 141 from the electrode base 15 and that of the electrode base 15 from the tongue base 142 as well as the length of the tongues and electrodes are chosen such that the longitudinal sides of the tongues 121 lie opposite the longitudinal sides of the electrodes 131 at a distance of, for example, 2 μm and the longitudinal sides of the tongues 122 lie opposite the longitudinal sides of the electrodes 132 at a similar distance. The two tongues 121 form with the two electrodes 131 two parallel-connected capacitances, which lie opposite the two likewise parallel-connected capacitances which are formed by the two tongues 122 together with the two electrodes 132. In addition, the arrangement of the tongues 121 with respect to their electrodes 131 is opposite to that of the tongues 122 with respect to their electrodes 132, in order that an

acceleration deflecting the tongues induces opposed changes in distance between tongues and electrode in the capacitances which lie opposite. In the case of this arrangement, the quiescent capacitance of the sensor is influenced by the parallel connection of a plurality of capacitances; and the sensitivity is increased by the evaluation of the difference of oppositely changing capacitances. In Figure 3, 30 denotes the lower edge of an etching window 30 of the back etching. Its position must be chosen such that, although the tongues remain rigidly connected to the tongue base, their tips can freely vibrate. The electrodes, on the other hand, are not only to be rigidly connected to the electrode base but, in addition, also connected to the lower layer 21 at at least one further point.

Fig. 4.

In Figure 4, a sensor which has been etched out of a two-layered support 10 with a lower layer 21 and an upper layer 20 is represented, the two layers forming a pn junction and an np junction respectively, on account of their different dopings, which junction isolates the upper layer 20 from the lower layer 21 upon connection in the non-conducting direction. Two U-shaped etched trenches 11, which completely penetrate the upper layer 20, together with in each case a lateral undercutting 22, have produced in the upper layer two tongues 12 extending from a tongue base 14, which tongues can vibrate in the plane of the support. Such a tongue 12 serves as moveable electrode of a differential plate capacitor with two fixed electrodes 131 and 132, which are formed by those parts of the bordering of the U-shaped etched trenches 11 which have remained parallel to the tongues 12. The isolation of the tongues 12 and of the electrodes 131 and 132 from one another takes place in the upper layer 20 by an isolation diffusion 23, which completely penetrates the upper layer 20. This is either a p-type diffusion, if the upper layer 20 is negatively doped, or an n-type diffusion, if the upper layer 20 is positively doped. The tongues 12 and the electrodes 131 and 132 are thus isolated both with respect to one another and with

respect to the lower layer 21 by pn junctions. In order to be able to evaluate the changes in capacitance of the differential plate capacitors upon deflection of the tongues 12 by means of a circuit, there is in each case a metal terminal 24 on the support surface 16 at the ends on the tongue-base side of the tongues 12 and of the electrodes 131 and 132. Deflection of the tongues 12 has the effect of increasing the capacitance between the tongue 12 and the electrode 131, for example, while the capacitance between the tongue 12 and the electrode 132 is decreased. With the parallel connection of a plurality of such differential plate capacitors, neighbouring fixed electrodes 131 and 132 have to be isolated from each other in order for the increase in capacitance on one side not to be compensated by the decrease in capacitance on the other side. In the exemplary embodiment represented, this takes place by means of an isolation diffusion 23, which completely penetrates the upper layer 20. Likewise suitable is an isolation trench, as represented in Figures 1 and 3.

Claims

1. Sensor for vibration measurement, in particular for acceleration measurement, the sensor being produced from a support (10) of monocrystalline material, from which at least one vibratable tongue (12) is etched out, and with means for evaluation of the deflection of the at least one tongue (12), characterised in that the tongue (12) is arranged vertically to the support surface (16), in that an electrode (13) is arranged opposite the tongue (12), in that tongue (12) and electrode (13) are electrically isolated from each other and in that the capacitive change between tongue (12) and electrode (13) is measurable.

2. Sensor according to Claim 1, characterised in that the support (10) has a lower layer (21) and an upper layer (20), which form either a pn junction or an np junction, on account of their negative or positive doping, and in that the isolation of the tongue (12), formed in the upper layer (20), and of the electrode (13) is formed by etched trenches (11), which completely penetrate the upper layer (20).

3. Sensor according to Claim 1, characterised in that the support (10) has a lower layer (21) and an upper layer (20), which form either a pn junction or an np junction, on account of their negative or positive doping, and in that the isolation of the tongue (12), formed in the upper layer (20), and of the electrode (13) takes place by isolation diffusions (23), which completely penetrate the upper layer (20).

4. Sensor according to one of the preceding claims, characterised in that a plurality of tongues are

respectively opposite an associated electrode.

5. Sensor according to one of the preceding claims, characterised in that each tongue (12) with the associated electrode (13) is assigned a further tongue with a further electrode, the further tongue having an opposite direction of movement, with respect to the further electrode, to the tongue (12) with the associated electrode (13).

6. Sensor according to one of the preceding claims, characterised in that the electrodes (131, 132) extend in the form of combs from an electrode base (15) and in that the tongues (121, 122) extend in the form of combs from at least one tongue base (141, 142).

7. Sensor according to one of Claims 1 to 3, characterised in that each tongue (12) is assigned a further electrode (132), the tongue (12) having an opposite direction of movement, with respect to the further electrode (132), to the direction of movement with respect to the one electrode (131).

8. Method of producing a sensor for vibration measurement according to one of the preceding claims, characterised in that the etched trench (11) of the sensor is etched with the aid of the photomasking technique, with lateral bounding surfaces running essentially vertically to the two main surfaces of the support (10) and with a bottom surface running essentially parallel to the two main surfaces, into the support (10) from the support surface (16) by anisotropic etching, for example reactive ion-etching or wet-chemical etching, in such a way that the upper layer (20) is completely etched through, and subsequently, for forming the at least one tongue (12), the part of the etched trench (11) which surrounds the tongue to be exposed is provided with a lateral undercutting (22) in the vicinity of its bottom surface.

9. Method of producing a sensor for vibration measurement according to one of Claims 1 to 7, characterised in that the etched trench (11) of the sensor is etched with the aid of the photomasking technique, with

lateral bounding surfaces running essentially vertically to the two main surfaces of the support (10) and with a bottom surface running essentially parallel to the two main surfaces, into the support (10) from the support surface (16) by anisotropic reactive ion-etching or anisotropic wet-chemical etching, in such a way that the upper layer (20) is completely etched through, and the exposure of the at least one tongue (12) takes place by a back etching to such an extent that, starting from an etching window (30) produced by a photo masking technique on the not yet structured underside of the support (10), the lower layer (21) is completely etched through by an anisotropic etching process.

10. Method according to Claim 9, characterised in that the etching window is chosen such that the fixed electrodes rest on the support material, at least at their two ends.

11. Any of the sensors substantially as herein described with reference to the accompanying drawings.

12. Any of the methods of producing a sensor substantially as herein described with reference to the accompanying drawings.

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